DAILY VARIATIONS OF TEMPERATURE AND WIND SPEED IN THE SURFACE BOUNDARY LAYER AT MIZUHO STATION, EAST ANTARCTICA

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Abstract: Micrometeorological observations at Mizuho Station were carried out from February 1979 to January 1980 by the members of the 20th Japanese Antarctic Research Expedition (JARE-20) and will be continued until January 1982 by other JARE members.

Characteristics profiles of temperature, wind and net radiation during all four seasons measured simultaneously on a 30 m tower are discussed in relation to the variation of net radiation. Especially, in winter, there is little variation of net radiation temperature or wind speed. In the lowest 30 m layer, stratification is usually stable. On the other hand, as the snow surface is warmed by the short-wave radiation in the summer season, the temperature shows a daily variation and the wind speed also shows a daily variation. The inversion layer gradually disappeared and unstable stratification occurred in the daytime.

1. Introduction

In February 1979 the POLEX-South (Polar Experiment in the Antarctic) program began at Mizuho Station.

Meteorological observations at Mizuho Station since 1976 have indicated that a katabatic wind of about 12 m/s blows continuously. The development of katabatic winds has notable consequences for the microclimate on Mizuho Plateau. A knowledge of the wind and temperature profiles is of importance for understanding the micrometeorological phenomena in the surface layer. In order to observe these phenomena, a tower was built at Mizuho Station, 70°42′S, 44°20′E, in January 1979, and observations were carried out from February 1979 to January 1980 by JARE-20. These will be continued until January 1982. Investigations of the wind and temperature profile in the stable stratification area were reported. MAKI (1974) reported the results of the micrometeorological observations at Syowa Station during the period from February 1971. LETTAU *et al.* (1977), KUHN *et al.* (1977) and

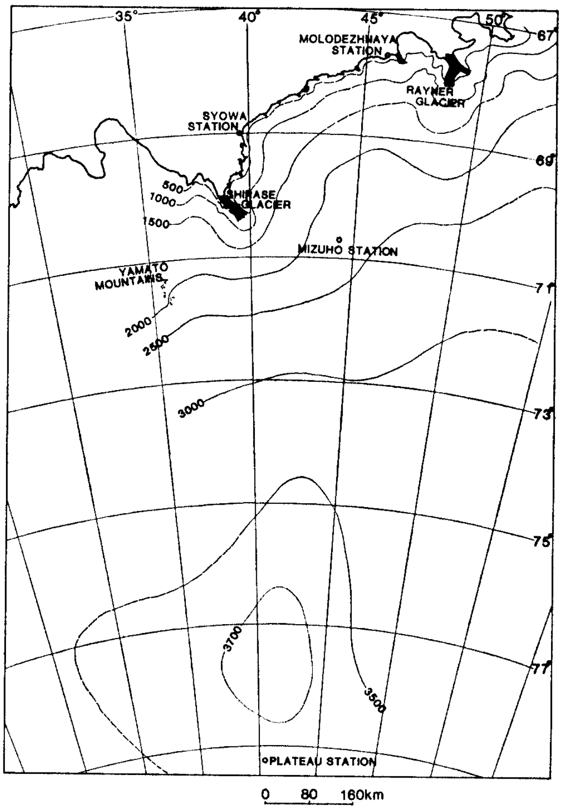

Fig. 1. The location of Syowa Station, Mizuho Station and Plateau Station.

RIORDAN (1977) reported results on the wind and temperature variations at Plateau Station in 1967. The location of Syowa Station and Plateau Station are shown in Fig. 1. Syowa Station is situated on Ongul Islands and is influenced by the sea and Plateau Station is situated in an inland Antarctic area where the katabatic wind is weak. Mizuho Station is situated between Syowa Station and Plateau Station, and the strong katabatic wind blows continuously.

2. Instruments and Data

2.1. *Thermometer*

The temperature was measured with platinum resistance type thermometers at seven levels (30, 16, 8, 4, 2, 1, 0.5 m) on a 30 m tower. The accuracy of these thermometers was ±0.5°C. To reduce the radiation, the thermometers were mounted within shileds made of stainless steel.

2.2. *Anemometer*

Three-cup anemometers were mounted on the aluminum pipe arms of the 30 m.

tower and wind speed was measured at the same level of the air temperature sensors. The accuracy was ± 1.0 m/s. Three-cup anemometers were made by Makino Instrument Co.

2.3. *Net radiation*

The net radiation was calculated by the following equation:

$$\begin{aligned} R_n &= S_n + L_n \\ &= S_d - S_u + L_d - L_u \end{aligned} \tag{1}$$

where S_n and L_n are the net radiation of shortwave and longwave radiation respectively, S_d, S_u, L_d and L_u are global, reflected shortwave, downward and upward longwave radiations. A detailed report of the radiometry was given by YAMANOUCHI *et al.* (1981).

2.4. *Data acquisition system*

The micrometeorological data acquisition system was constructed by Kaijo Denki Co. This system included a digital clock, a voltmeter, a scanner, a printer and two digital magnetic recorders. Data were sampled once a minute and recorded on magnetic tape, and average, maximum and minimum data were calculated and printed out on the printer every day.

The radiation data acquisition system was constructed by Eko Instrument Co. This system was a slightly modified Sharp Model PC-7200 which included a small printer and included a digital clock, a scanner and a digital magnetic recorder. Data were sampled once a minute and recorded on magnetic tape; average data were calculated every thirty minutes and printed out. Reading out of these data and statistical calculations were carried out on the M160-II computer at the National Institute of Polar Research.

The more detailed installation and performance of the measurement system in 1979 were discussed by MAE *et al.* (1981).

3. Results of Observation

3.1. *Some features of the wind and temperature variation*

Figures 2–5 show the air temperature and wind speed at different levels on the 30 m tower for 4 days. The value of the temperature and wind speed are given as 20-minute averages.

The wind speeds in these four cases were almost 10 m/s at the 4 m level. These four cases were selected for the reason that the amount of cloud on these days was less than 10% and katabatic wind blew continuously on all of these days.

Figure 2 illustrates the daily variation of the temperature and wind speed on April 15. The difference between the daily maximum temperature and daily mini-

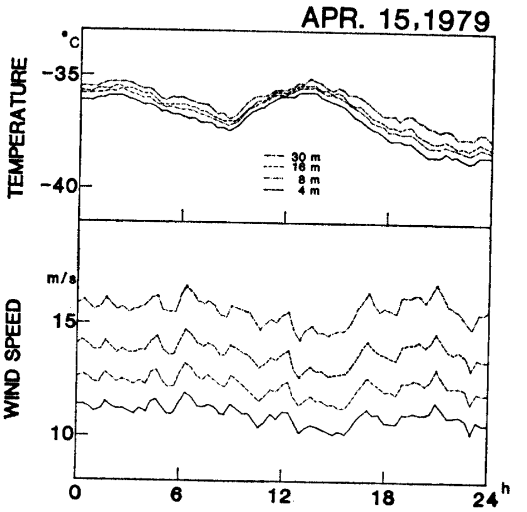

Fig. 2. The daily variation of the temperature and wind speed on April 15, 1979.

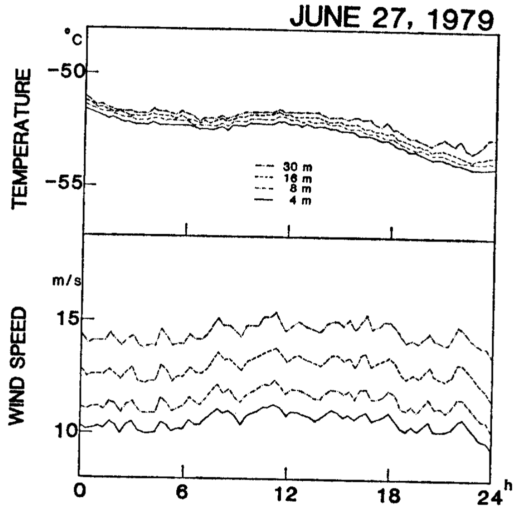

Fig. 3. The daily variation of the temperature and wind speed on June 27, 1979.

mum temperature at the 30 m level was 2.6°C; at 4 m level it was 3.0°C. The maximum of the difference between the temperatures at the 30 m level and the 4 m level was 1.3°C. The lapse rate of this inversion layer was −0.05°C/m.

On the other hand, the variation of the wind speed at the 30 m level was the same as at the lower level; a diurnal variation of the wind speed was detected.

Figure 3 shows the variation of the temperature and wind speed during a sunless period. The daily variation of the temperature was small compared with Fig. 2. The difference between the daily maximum and minimum temperature was 2.5°C at the 4 m level and 2.4°C at 30 m. The lapse rate of this inversion layer between 30 m and 4 m was −0.05°C/m; and the lapse rate in both daytime and nighttime was negative. A diurnal variation of the wind speed could not be detected. As the value of the net radiation which is shown in Fig. 6 was constant all day during a sunless period, it is considered that the daily variation of temperature and wind speed was not almost observed.

Figure 4 reveals the large variation of the temperature on the vernal equinox day. The difference between the daily maximum and minimum temperatures was 6.7°C at 30 m. The temperature inversion gradually disappeared after the minimum temperature in the morning and then an inversion began to appear, when the maximum temperature had occurred. The daily variation of wind speed was remarkable. Especially, the minimum value of wind speed occurred at about 1630, about three hours before the time when the net radiation became zero.

Figure 5 shows the record of the temperature and wind speed on a mid-summer

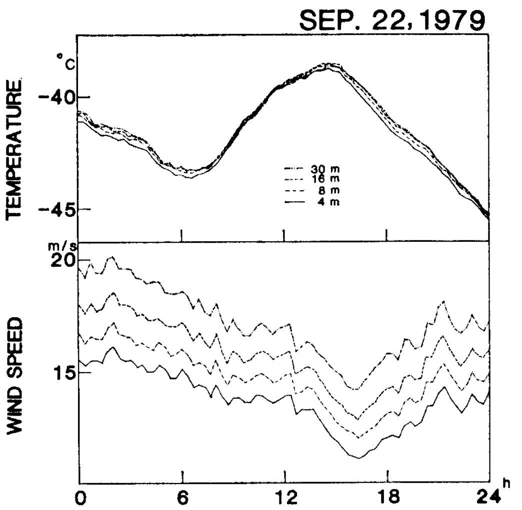

Fig. 4. The daily variation of the temperature and wind speed on September 22, 1979.

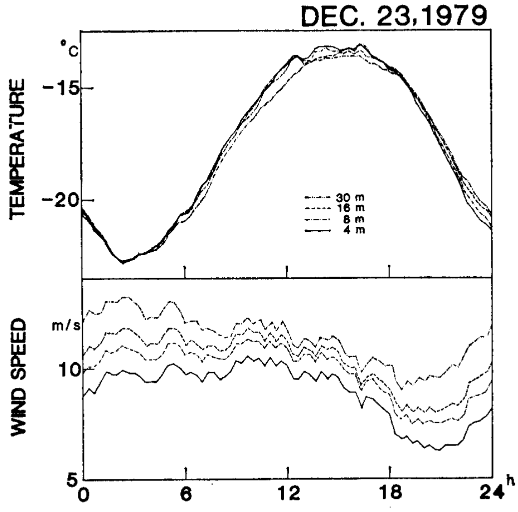

Fig. 5. The daily variation of the temperature and wind speed on December 23, 1979.

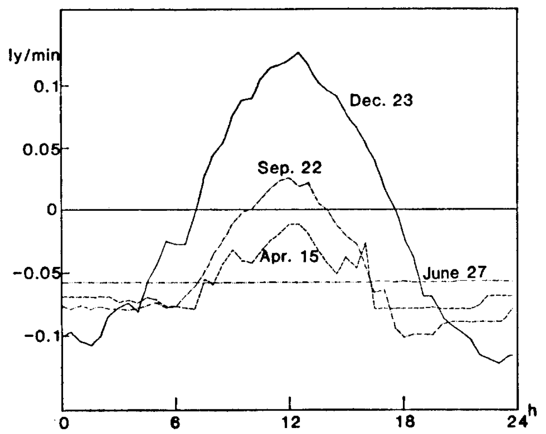

Fig. 6. The daily variation of the net radiation on April 15, June 27, September 22 and December 23, 1979.

day. The value of the net radiation became larger than 0.1 ly/min at noon as seen from Fig. 6. The difference between the daily maximum and minimum temperatures was 9.1°C at 30 m; the temperature at 4 m was higher than that at 30 m between 0200 and 1800, in other words, the inversion layer disappeared and unstable stratification formed during this period. The daily variation of wind speed was remarkable and the minimum value of wind speed occurred about three hours before the net radiation became zero.

3.2. *Some characteristics of the temperature and wind profiles*

Figures 7 and 8 show the shape of the temperature profiles every three hours in winter and summer. In winter, all profiles are similar and an inversion layer was observed all day. The lapse rate in the inversion layer was not large, since a strong wind, about 15 m/s, blew continuously. The 1 m level showed the lowest temperature all day. In summer, as the variation of the difference between the surface temperature and the 0.5 m level temperature was too large to be shown, the differences between the temperatures at 4 m and at the higher level are shown in Fig. 8. An

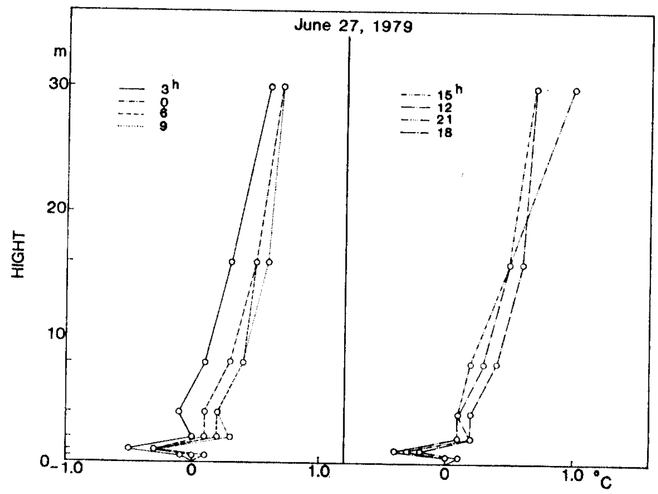

Fig. 7. The difference of the temperature between the snow surface level and the other levels.

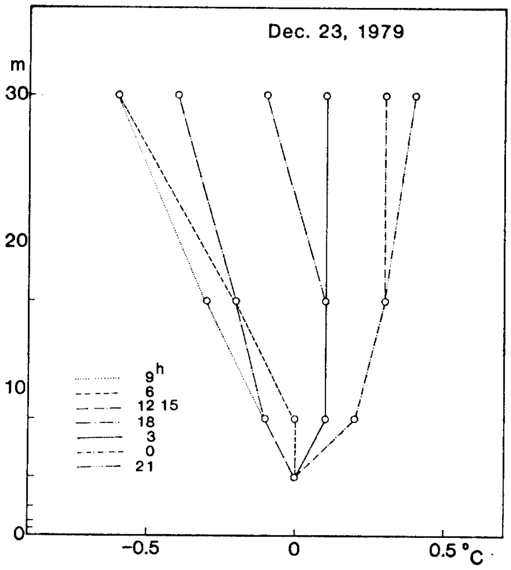

Fig. 8. The difference of the temperature between the 4 m level and other levels.

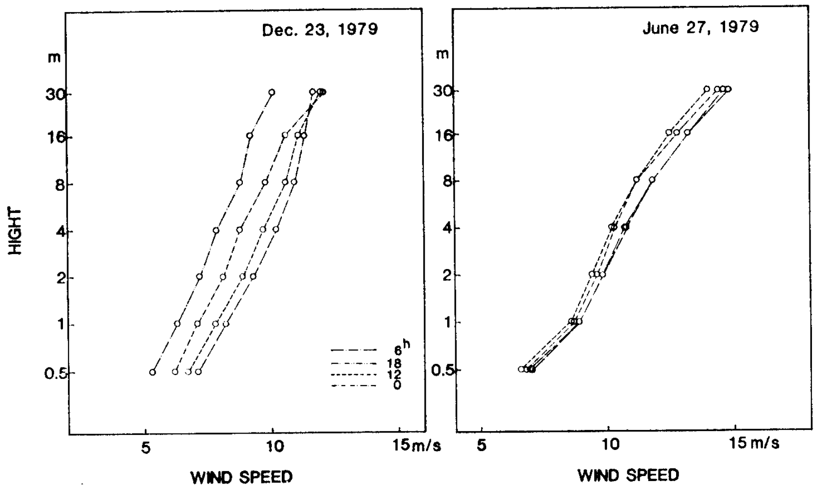

Fig. 9. The shapes of the wind profiles on June 27 and December 23, 1979.

inversion layer was formed gradually from near the surface since 1800 and a highly stable layer was formed about 0000.

The shapes of wind profiles in winter and summer every six hours are shown in Fig. 9. The nondimensional wind shear ϕ is defined by the following formula:

$$\phi=\frac{kz}{u^*}\times\frac{\mathrm{d}u}{\mathrm{d}z}, \qquad u^*=\frac{\tau_0}{\rho} \tag{2}$$

where k is the von Kármán constant, u^* is the frictional velocity, u is the wind speed, z is the height above the snow surface, τ_0 is the shearing stress (approximately constant in the boundary layer) and ρ is the air density. Suppose that the stratification is neutral, $\phi=1$. For stable stratification $\phi>1$ and for unstable $\phi<1$. Figure 10 shows the wind profiles for $\phi=1$, $\phi>1$ and $\phi<1$. As shown in Fig. 11 all shapes of

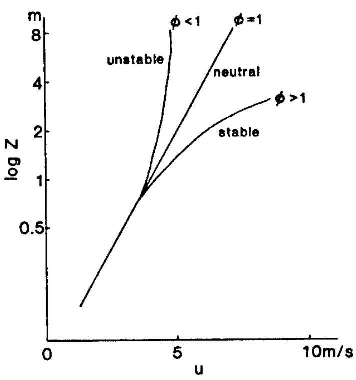

Fig. 10. Stability of the wind profiles in the lower boundary layer.

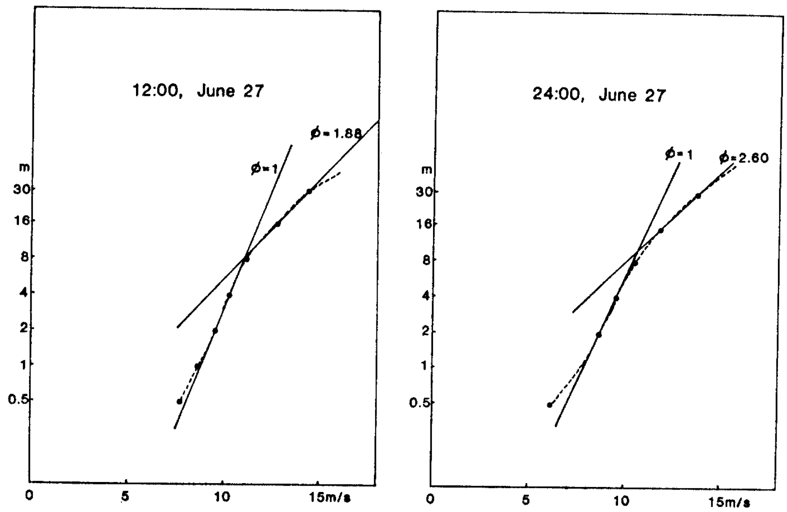

Fig. 11. Wind profiles on June 27, 1979. The line for $\phi=1$ is the neutral line. Dashed lines show real wind profiles.

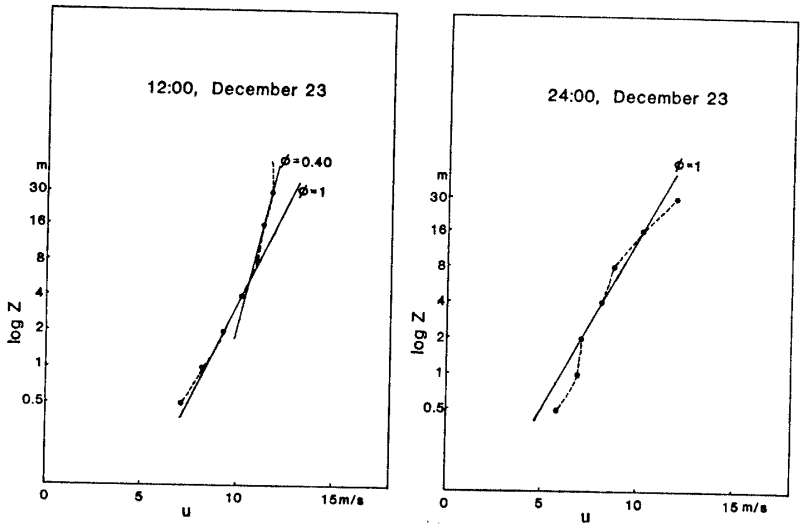

Fig. 12. Wind profiles on December 23, 1979. The line for $\phi=1$ is the neutral line. Dashed line show real wind profiles.

wind profiles in winter were similar to the graph of $\phi>1$ in Fig. 10, *i.e.*, stable stratification continued all day. As shown in Fig. 12 in summer the shape of wind profiles at 0600 and 1200 were similar to the graph for $\phi<1$ in Fig. 10, and the shapes at 1800 and 2400 were similar to that for $\phi=1$, *i.e.*, in the daytime unstable stratification occurred. Using the wind speeds at the 2 m and 4 m levels the values of u^* were calculated, because the stratification is usually neutral in the layer very near surface. Using these values of u^* and the wind speeds at the 30 m and 16 m levels the values of ϕ were calculated and are shown in Figs. 11 and 12. In winter ϕ was larger than 1 and gradually became larger from 1200 to 2400. In summer ϕ was smaller than 1 and stratification was unstable in the daytime.

4. Conclusion

The daily variations of wind speed and air temperature were remarkable in the summer season but were small in the winter season at Mizuho Station. An inversion layer was maintained all day in winter; it disappeared in the daytime in summer as seen from the profiles of wind speed and air temperature on a 30 m tower at Mizuho Station. The phenomena were considered in relation to the variation of net radiation. Whether the stratification was stable or not was found from the wind profiles in this paper. The variation of the height of the inversion layer will be described using data obtained by the members of JARE-21.

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